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A Pilot Cueing System for Autorotation

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Overview

- Project Motivation
- Research Question(s)
- Collaboration with Georgia Institute of Technology
- Facilities
- Cues for Manually Controlled Flight
- Key Results
- Discussion/Concluding Remarks
- Future Work
- Further Reading
- Acknowledgements

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Motivation

- The autorotation maneuver to land follows a partial or complete engine failure or some other catastrophic event in a helicopter*

VIDEO: https://youtu.be/qEgr2cOJjIo

*Video courtesy: V. Dimitris, YouTube, 2007

Motivation

- A successful autorotation outcome requires fast pilot reaction times and appropriate control actions to be made
- This is particularly true for the phases of the maneuver close to the ground
- It is a complex and difficult maneuver particularly in degraded visual environments (DVE), night-time operations, or low-energy flight conditions
- Even well trained, highly motivated pilots can encounter difficulties

Inappropriate Autorotation Training: Police AS350

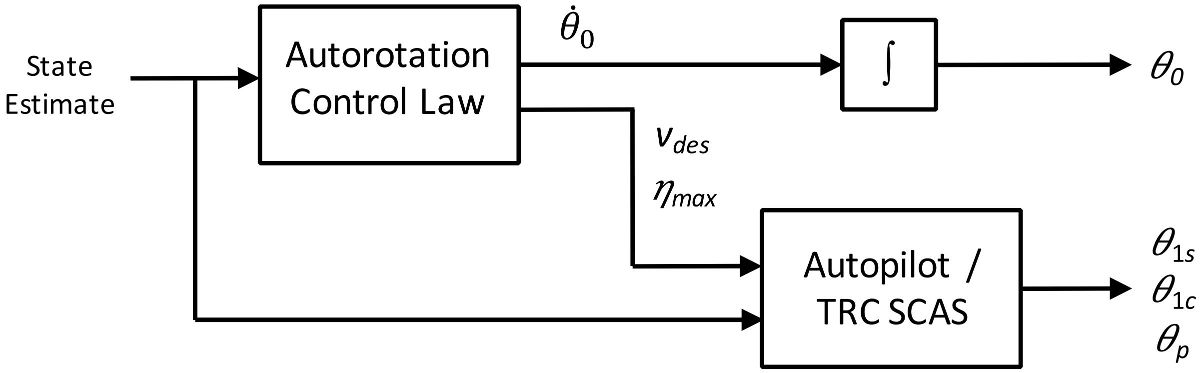
Posted by Aerossurance on Aug 18, 2018 in Accidents & Incidents, Helicopters, Human Factors / Performance, Safety Management, Special Mission Aircraft | 0 comments

Research Question(s)

- Can additional cueing be provided to assist a pilot to carry out a successful autorotation maneuver and, if so, what form(s) should this take?
- There are various possibilities:
  - Discrete (a cue at specific points in the maneuver)
  - **Continuous (cues that persist throughout the maneuver)**
- And for each of these:
  - **Visual (e.g. text, symbols, head-up or head-down)**
  - Audio (e.g. tone, spoken words)
  - Tactile (e.g. stick shaking, force feedback)

Collaboration with GT

- Georgia Institute of Technology (GT) have developed an autonomous autorotation controller, from entry to touchdown (deterministic at runtime)[1]
- Controller designed to interface with a standard autopilot or stability and control augmentation system (SCAS) capable of accepting translational rate commands (TRC)

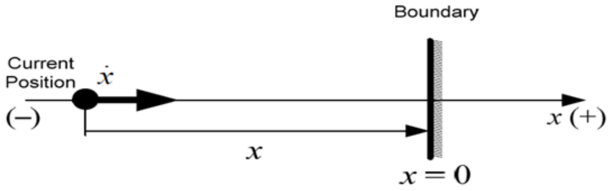


- Can use the outputs of this controller to derive either desired aircraft states or control inceptor positions to cue the pilot
- The controller uses a number of phases for the maneuver, the transition between them being triggered by altitude and/or **time-to-contact**

1. Sunberg, Z., Miller, N., Rogers, J., "A Real-Time Expert Control System for Helicopter Autorotation," Journal of the American Helicopter Society, April 2015

Collaboration with GT

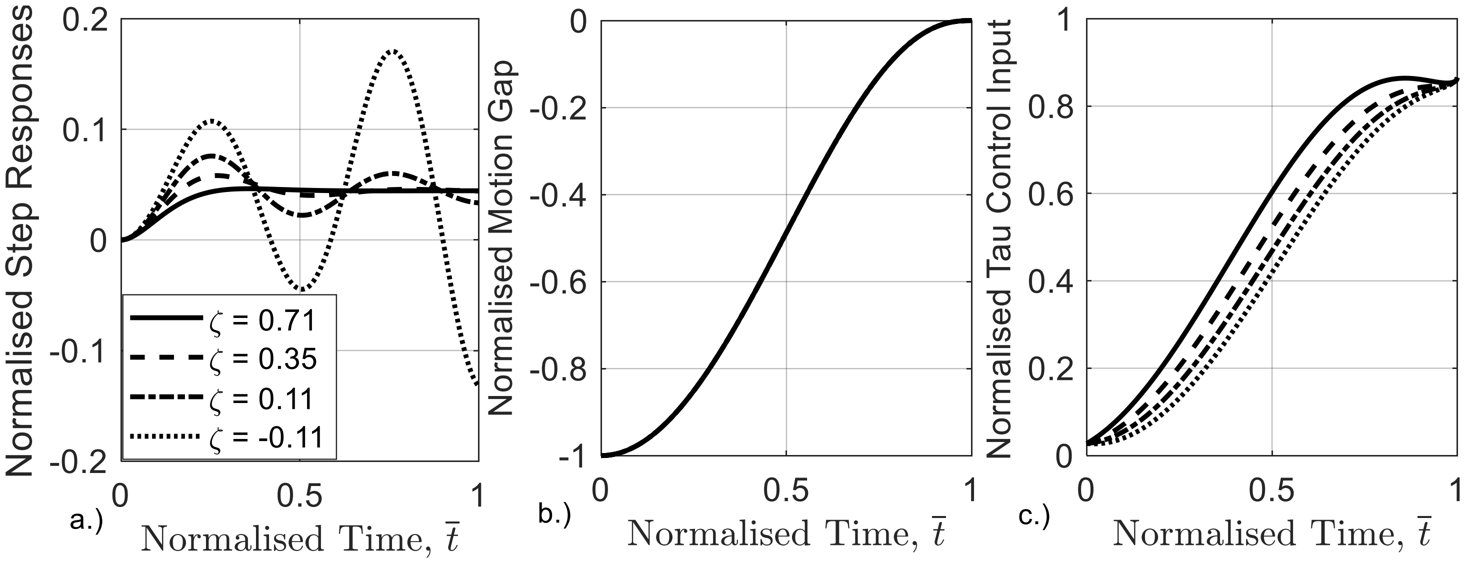
- University of Liverpool has a particular interest in using time-to-contact (or tau) as a flight control variable



$$\tau(t) = \frac{x(t)}{\dot{x}(t)}$$

$x(t)$ ⟶ motion gap

$\dot{x}(t)$ ⟶ gap closure rate



- Supplemental research question – is there any practical advantage to using ‘tau’ to improve the cueing provided to the pilot during autorotation?

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Facilities

- HELIFLIGHT-R: a 6 degree-of-freedom motion flight simulator
- Aircraft model in FLIGHTLAB (FLIGHTLAB Generic Rotorcraft: UH-60 ‘like’)
- Moog Motion base and Control Loaders
- Aircraft displays in VAPS-XT (Head-Up initially), outside world – Vega Prime
- GT/UoL algorithm integrated into the aircraft model
- Simulated flight test campaigns using engineer and professional (former test) pilots

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Why Not Automate?

- One of our first activities, was to look at automated controllers: one based on GT algorithm, one based upon tau-of-height

GT Algorithm
'Out of the box' VIDEO:

https://youtu.be/VR-JUR5q9p8

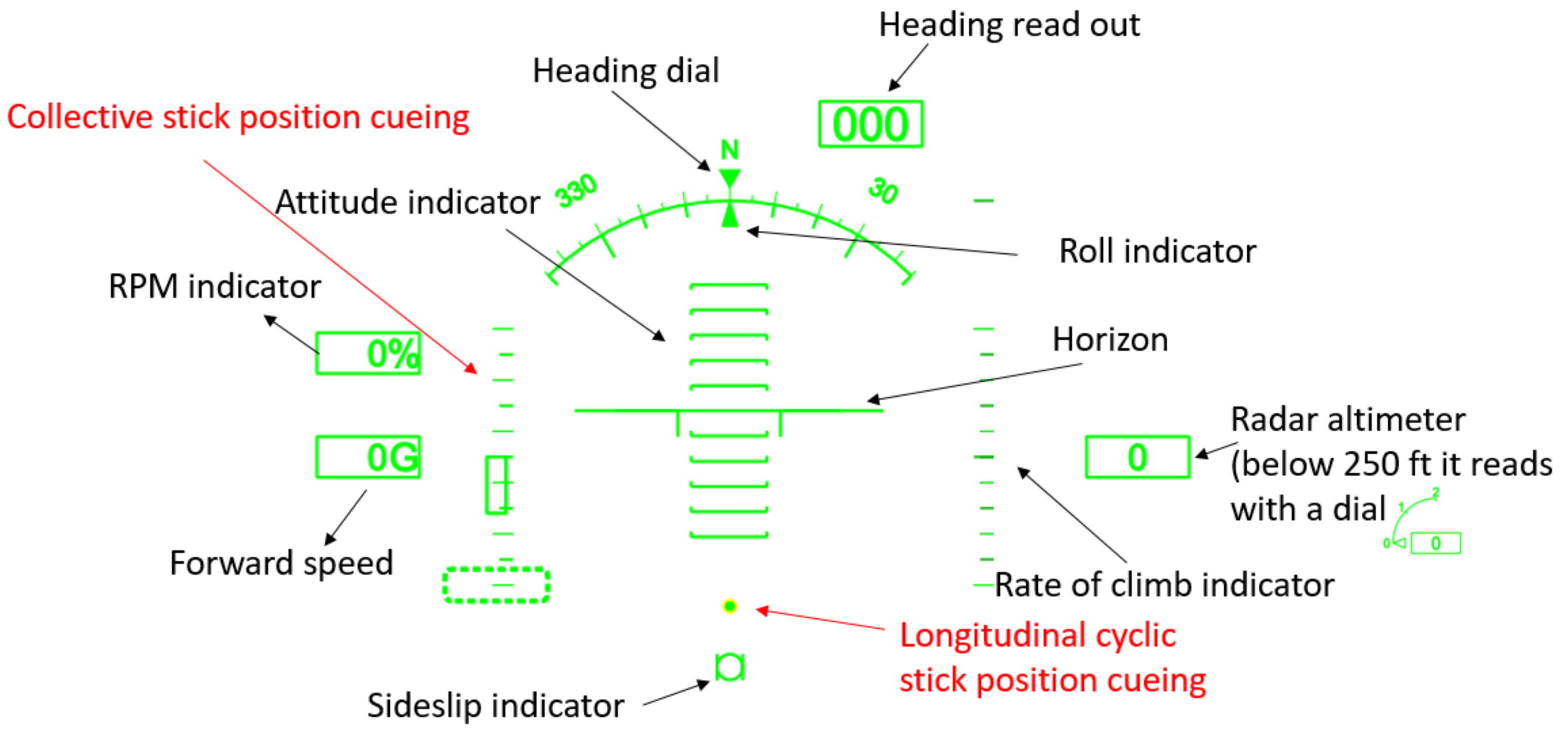
UoL Algorithm
Tau-of-Height VIDEO:

https://youtu.be/kurPqU2aD9I

- BUT, pilots 'not keen' on automation in such an emergency situation so close to the ground

Cues for Manually-Controlled Flight

- A number of visual cueing techniques have been developed/tested (driven by GT algorithm)
- Today will focus on continuous cues, head-up (pilots' preference to be looking out of the window)



Cue name: CC1

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Cues for Manually-Controlled Flight

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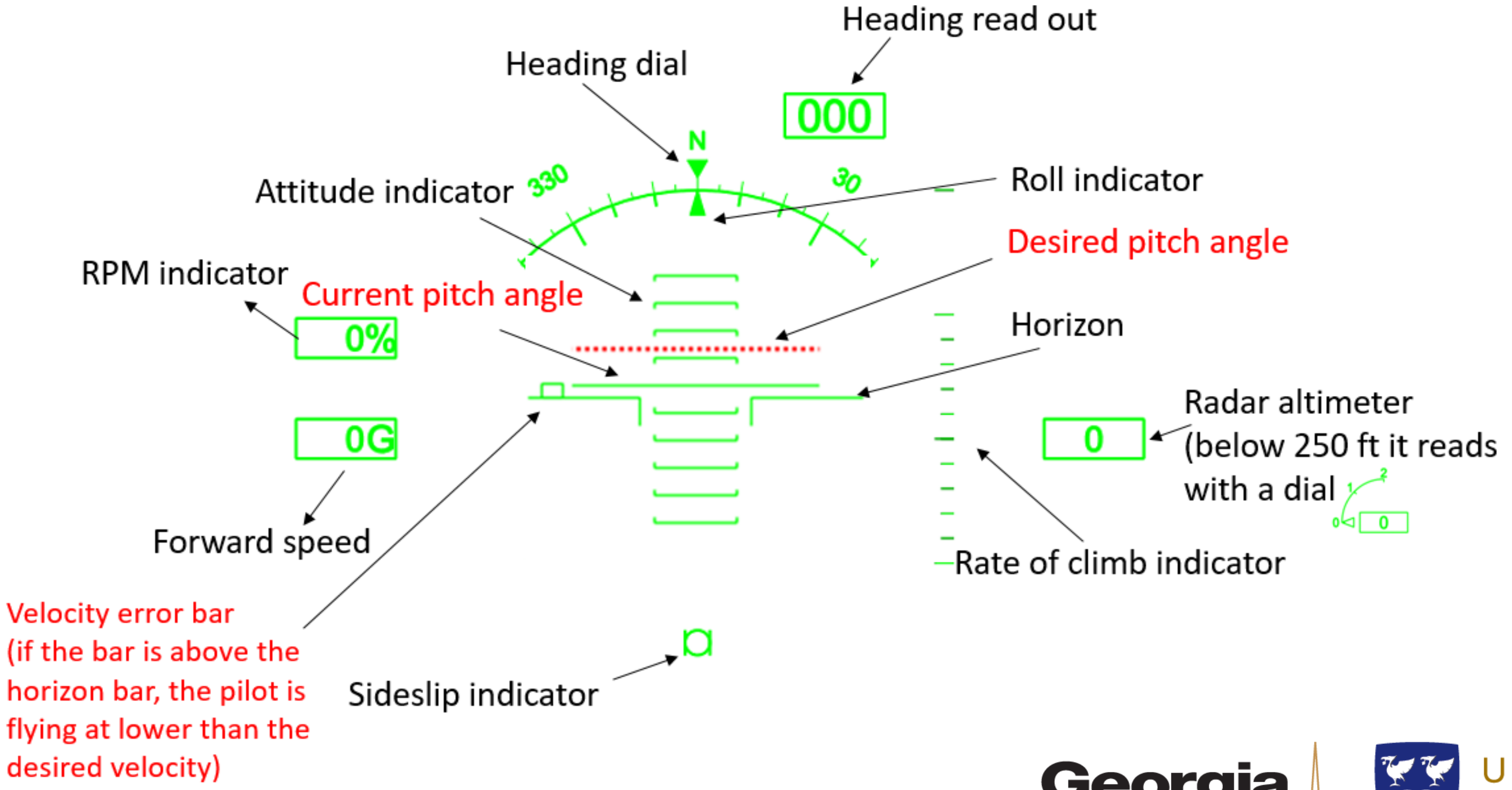
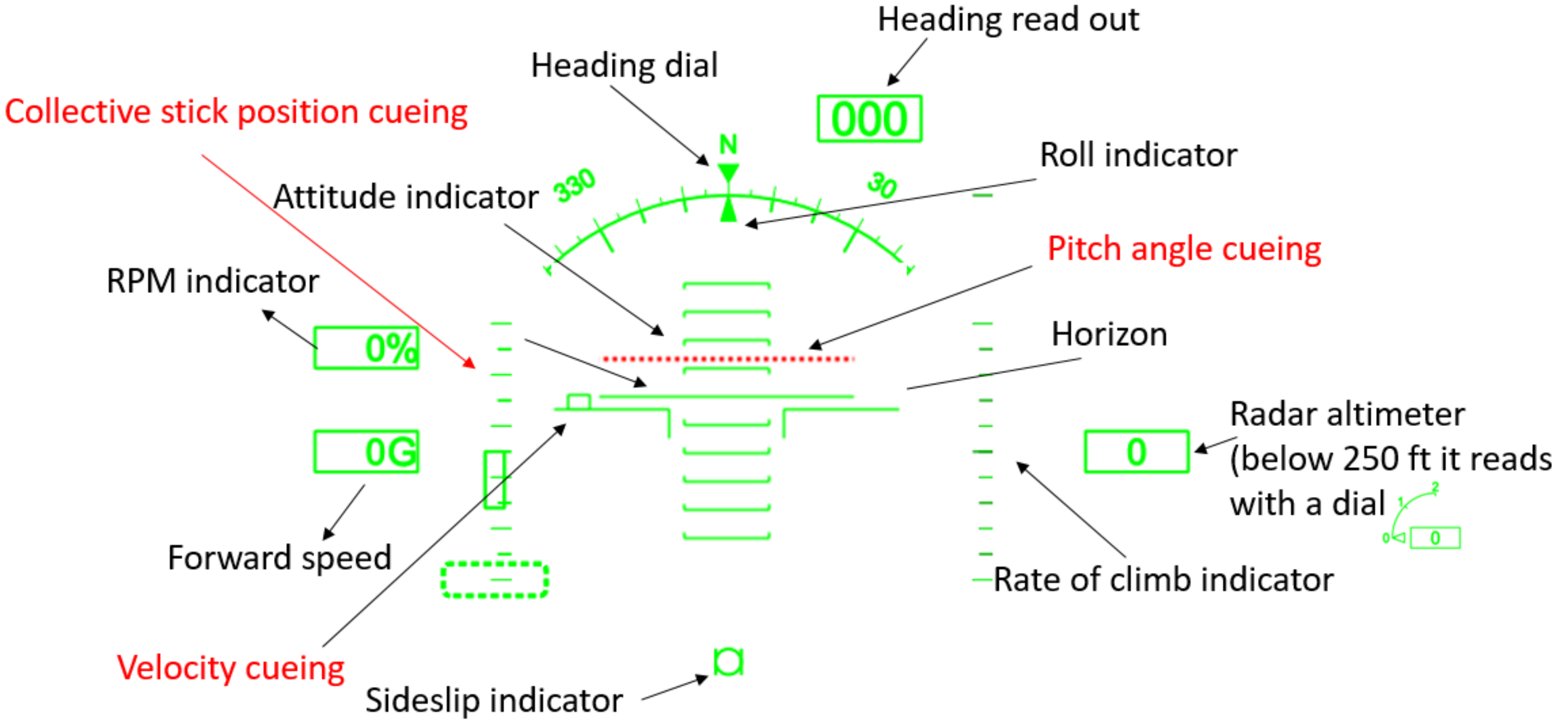


Cue name: CC2

Cues for Manually-Controlled Flight

- A number of visual cueing techniques have been developed/tested (driven by GT algorithm)
- Today will focus on continuous cues, head-up (pilots' preference to be looking out of the window)



Cue name: CC3

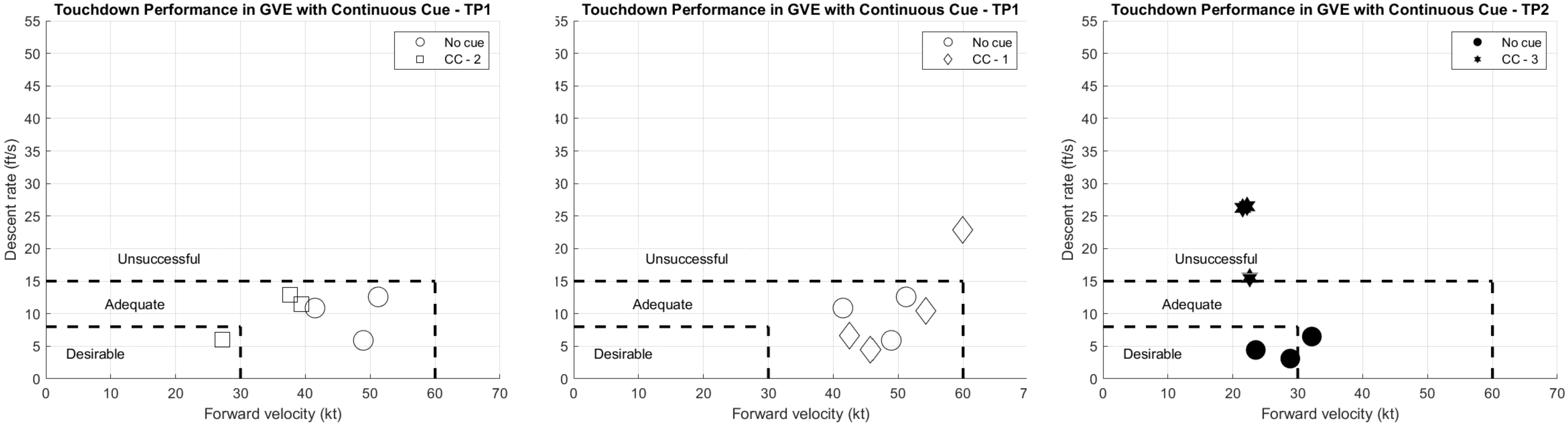
Key Results

- An example autorotation using CC-2 (pitch angle and speed cueing)

VIDEO: https://youtu.be/NbDDsZHCKsY

Key Results – Objective Evaluation

- A mixed set of results
- Sometimes cueing improved pilot performance, sometimes it made it now worse, sometimes it did make the outcome less favorable



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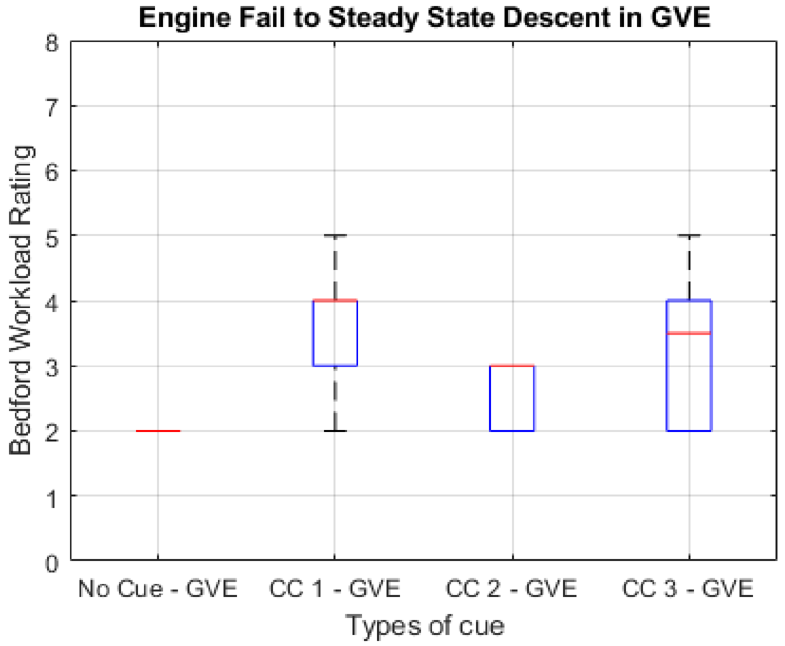
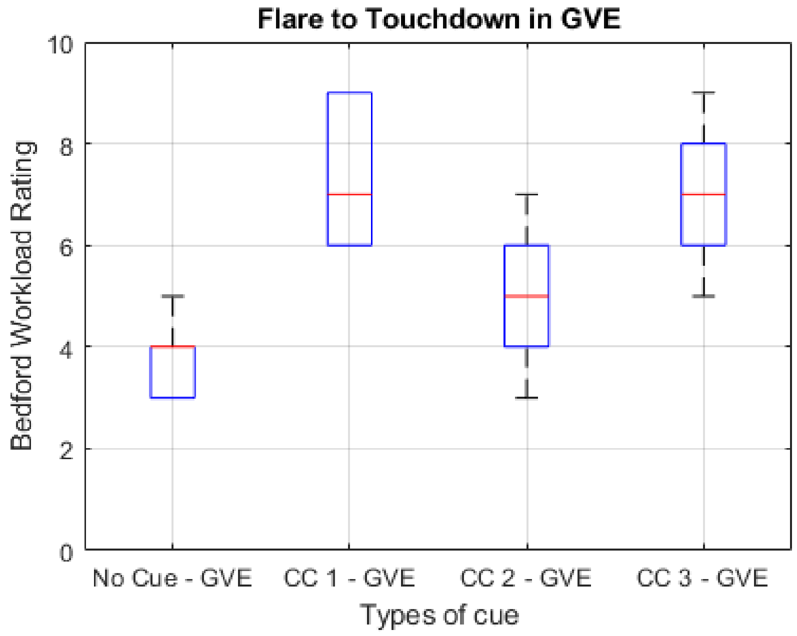
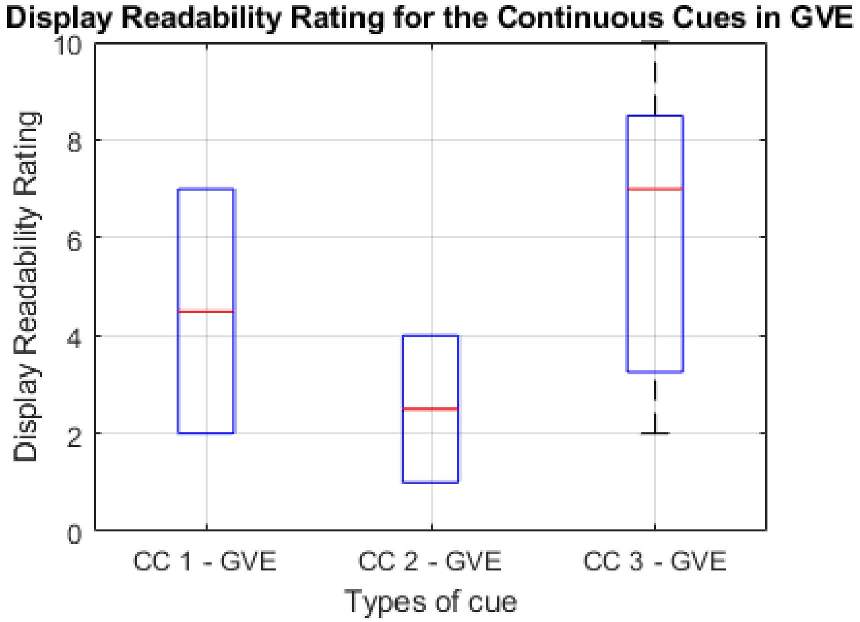
Key Results – Subjective Evaluation

- A slightly clearer set of results
- A slight ‘preference’ for CC2, both in terms of workload, and in readability







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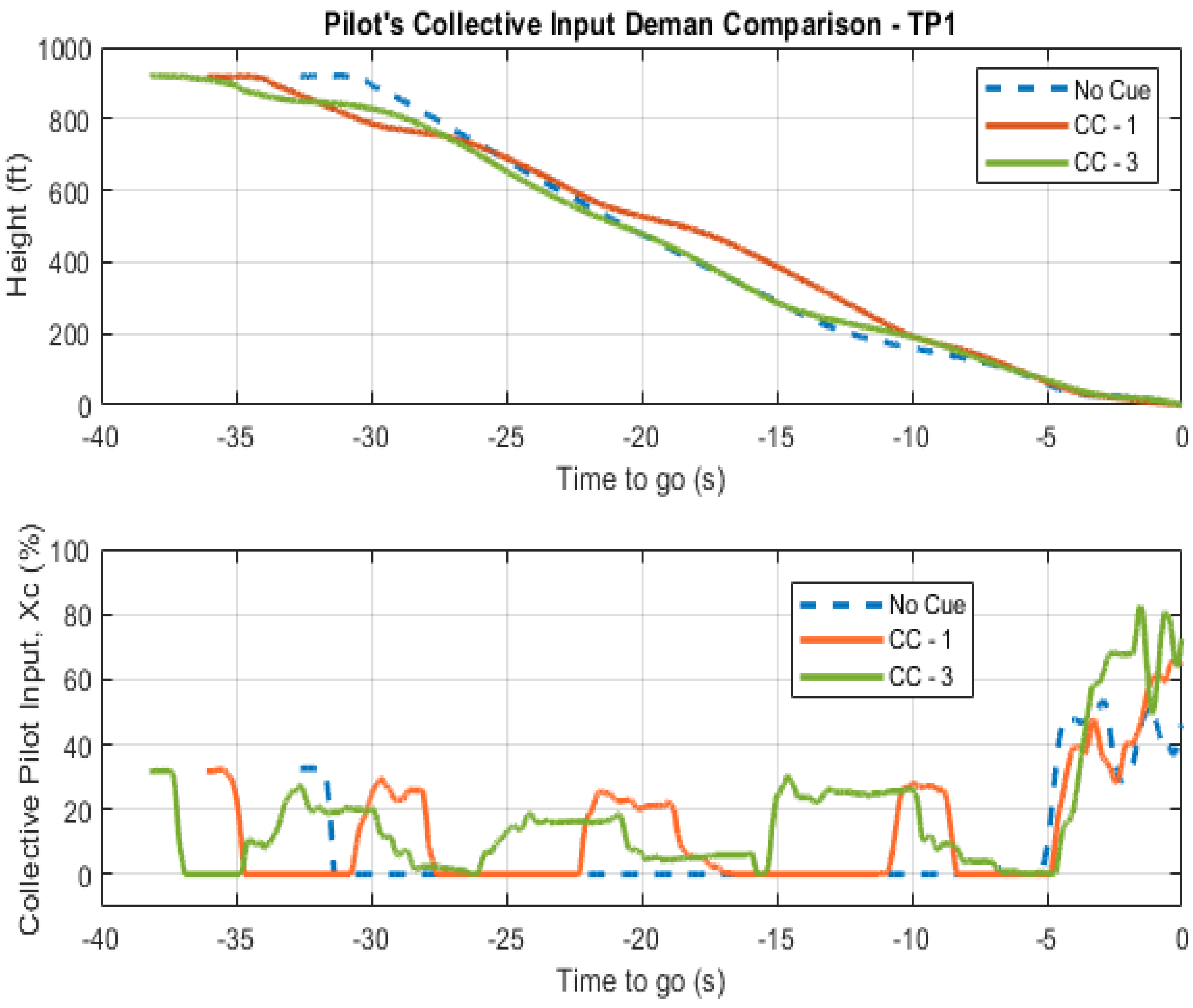
Key Results – Subjective Evaluation

- Subjective results partially explicable by considering the demands made on the pilot by the algorithm/display
- ‘Unusual’ collective demands c.f. their normal technique
- Also, given their position on the HUD, difficult for pilots to follow cues quickly due to their scan pattern



Discussion/Concluding Remarks

- Still very much, a work in progress
- Both GT and UoL algorithms provide an automated autorotation capability but this approach is not favored by pilots
- GT algorithm has been used to cue pilot with commands to be followed to complete an autorotation
- Pilots most favour the pitch angle cueing method over the stick position indications
- Collective demands are too ‘dynamic’ for either pilot comfort or ability to follow precisely
- Pitch angle cue described as ‘intuitive’ and ‘easy to follow’

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Future Work

- GT algorithm to be tuned further
- New cue driver algorithm under development, based on low-order model predictions
- Couple the above with tau-guidance in appropriate phases
- Compare Head-up with Head-down scenario
- Provide a wider suite of audio and haptic cueing to either complement or use instead of the visual cues

If you would like more information…

1. Jump, M, Cameron, N , Fell, T, Rogers, J, Strickland, L and Repola, C (2017) *Handling Qualities Assessment of a Pilot Cueing System for Autorotation Maneuvers*. In: AHS Forum 73, 2017-05-09 - 2017-05-11, Fort Worth, Texas
2. Eberle, Brian., Rogers, Jonathan., Jump, M. and Cameron, Neil. (2018) *Time-to-Contact-Based Control Laws for Flare Trajectory Generation and Landing Point Tracking in Autorotation*. In: AHS International's 74th Annual Forum and Technology Display; The Future of Vertical Flight, 2018-05-15 - 2018-05-17, Phoenix, Arizona, USA
3. Jump, Michael., Alam, Mushfiqul., Rogers, Jonathan. and Eberle, Brian. (2018) *Progress in the Development of a Time-To-Contact Autorotation Cueing System*. In: 44th European Rotorcraft Forum, 2018-09-18 - 2018-09-20, Delft, Netherlands.
4. Jump, M., Alam, Mushfiqul., Cameron, Neil., Fell, Th., Rogers, Jonathan., Eberle, Brian., Strickland, L. and Repola, C. (2018) *Summary of Progress In The Development Of A Time-to-contact Autorotation Cueing System*. In: International Powered Lift Conference 2018, 2018-11-13 - 2018-11-15, We The Curious, Bristol
5. Eberle, Brian., Rogers, Jonathan., Jump, M. and Cameron, Neil. (2018) *Flight Simulation Assessment of Autorotation Algorithms and Cues*. In: AHS International's 76th Annual Forum and Technology Display; The Future of Vertical Flight, 2020-10-06 - 2020-10-08, Virginia (virtually), USA
6. Alam, M , Jump, Michael. and Cameron, Neil. (2019) *Can Time-To-Contact Be Used To Model A Helicopter Autorotation?* In: 8th Asian/Australian Rotorcraft Forum, 2019-10-30 - 2019-11-02, Ankara, Turkey
7. Alam, M., Jump, M., Eberle, B., & Rogers, J. (2020). *Flight simulation assessment of autorotation algorithms and cues*. In Vertical Flight Society's 76th Annual Forum and Technology Display.

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Our simulator Test Pilots

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Thank you for your attention

Any questions?

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